



Geochemical Characterization

Geochemical characterization methods

- Lithology and alteration zones
- Whole rock analysis
- Mineralogy
- Sulfur analysis
- Static testing
- Short term leach tests (NV MWMP; CA WET)
- Kinetic testing
- *See Maest et al., 2005 for more details*

Sulfur analysis

- Kinds of sulfur: total, pyritic, sulfide, organic, sulfate
- Part of acid-base accounting testing; distinguishes between forms with more (pyritic, sulfide) and less (organic, sulfate) acid generation potential (AGP)
- Oxidation of ground sample with acid and measurement of S by spectrophotometer (LECO); removal of non-sulfide minerals to determine sulfide S.
- Does not confirm identity of minerals that contain the sulfur; can overestimate (for jarosite, iron sulfates) or underestimate (for chalcopyrite, galena) AGP (Lapakko, 2002).

Static testing

- Determines the total amount of acid-generating and acid-neutralizing material in a mine sample
- NOT for predicting long-term behavior
- Methods
  - acid-base accounting (ABA)
  - net acid-generating (NAG)
  - net carbonate value (NCV)

Static tests: General ABA methods

- Pulverize and dry sample
- Acid potential: Calculate total S (combustion to SO_2, measure by IR), subtract sulfate S (dissolve in HCl)
- Neutralization potential: Add acid to low pH (or pH 6 Lapakko), (rate fizz of sample, heat, add *T. ferroxidans* - BCRC), back-titrate to pH 7 (Sobek) or 8.3 (modified Sobek) with NaOH (silicates)
- NP estimates: Sobek>modified Sobek>BC Research>Lapakko

Static tests: NAG and NCV

- NAG: Add H_2O_2, react until stops fizzing, boil, titrate to pH 4.5 with NaOH
  - Commonly used in Australia
  - Screening method only
  - Doesn't distinguish between AP and NP
- NCV (Newmont): IR detection for TIC and S (total – residual S after 1 hr 550^{o}C)
  - Only includes carbonate minerals in NP
  - Can overestimate NP if siderite or Fe-silicates present

Static tests: Main Sources of Uncertainty

- Particle size
  - Crushed and mixed rock overestimates “liberation” of AG and AN materials
  - Use mineralogy and available surface area rather than ABA
- Effect of temperature, pH, test duration
  - Elevated T, final pH <6: overestimate ANP (silicates)
  - Modified Sobek and Lapakko pH6 most reliable and conservative
- Mineralogy unknown
  - Compare to “mineralogic” AP and NP
  - Especially important for low S, low NP wastes

Emigrant Project, NV: Comparison of static and kinetic test results

Rock Type1	NP:AP	NNP ($TCaCO_3/k$)	NCV ($\%CO_2$)	Humidity Cell (final pH)[4]	Paste pH < 6?	Acid-generating by Newmont Method[5]?
C/FW	0.40	-22.2	-0.54	7.25	No	Yes
W	0.80	-1.1	0.31	6.45*	No	No
W	0.13	-6.5	0.15	6.27*	No	No
W	<0.06	-5.3	0.1	5.37*	No	No
W	2.32	2.9	0.3	5.97*	No	No
W	<0.04	-7.2	0.11	4.98*	Yes	Yes
W	1.73	9.6	0.6	5.83*	No	No

Short-term leach testing

- Measures the readily soluble components of mine wastes
- Methods
  - Synthetic precipitation leaching procedure (SPLP) (20:1 = water:rock ratio)
  - Multiple extraction procedure (MEP)
  - Toxicity characteristic leaching procedure (TCLP)
  - Nevada meteoric water mobility procedure (MWMP) (1:1)
  - California waste extraction test (WET) (10:1)
  - Extraction procedure toxicity test (EP Toxicity)
  - British Columbia special waste extraction procedure and modification (BC SWEP) (3:1)
  - Various sequential extraction techniques
  - Shake extraction test
- Some tests have regulatory levels (100x MCL)

Short-term Leach Tests: Main Sources of Uncertainty

- Use of unweathered materials should be avoided
- NOT for predicting long-term behavior – only 18-48 hr tests
- Water:rock ratio (Nevada MWMP has lowest w:r ratio, more conservative for arid climates)
- Instead of short-term leach tests, could use “first flush” from longer-term kinetic testing

Kinetic testing

- Used to estimate the longer-term contaminant leaching potential and to estimate rates of oxidation and dissolution of materials
- Laboratory kinetic tests
  - humidity cell
  - column
- Field kinetic test
  - waste rock or tailings test piles
  - wall washing
  - Minewall approach (Morin and Hutt, 2004)

Kinetic tests: General methods

- Crush rock (<6.3 mm for waste rock, 150 μm for tails), place in column
- HCT: 3-d alternating humid air/dry air cycles, flush every week, 20+ wks
- Measure pH, sulfate, metals, etc. in leachate
- Column tests – larger columns and particle size (<~25 mm), "trickle leach"

2-yr kinetic tests, Montana Tunnels, MT
photo by Ann Maest

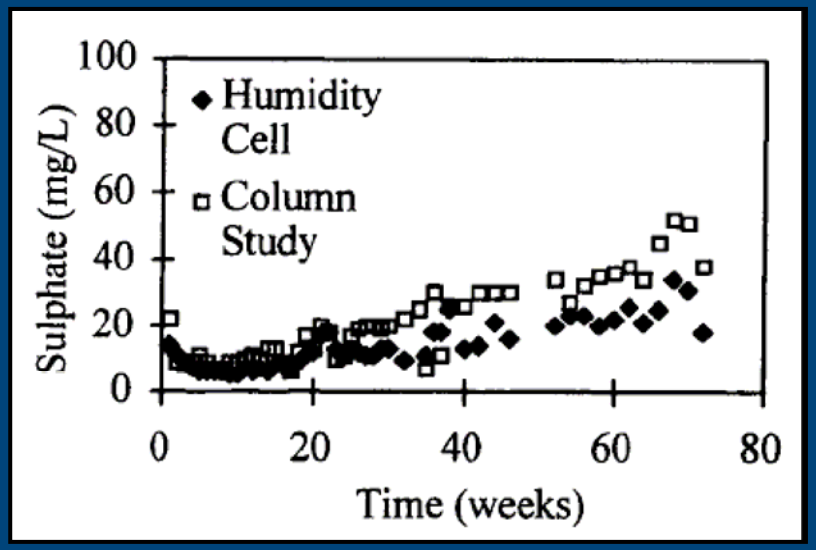
Kinetic tests: Sources of uncertainty

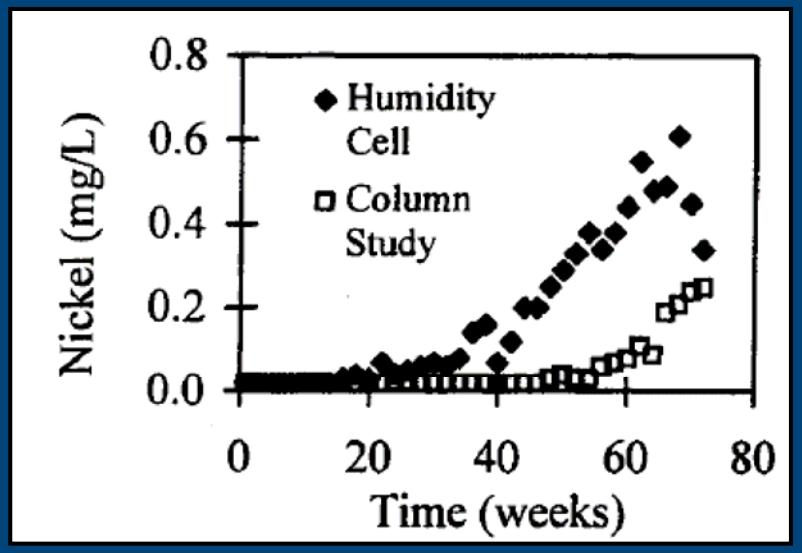
- Field/lab discrepancies
  - Lab tests not representative of field conditions: lab overestimates weathering rates, underestimates length of contaminant generation
  - Use particle size/meteorologic conditions similar to field and longer tests
  - Account for differences in temperature, particle size, spatial variability of sulfide-bearing rock, hydrological factors (preferential flow), availability of oxygen
  - Know particle size distribution, surface areas, identity and availability of AG and AN minerals
  - Express weathering rates relative to available surface area

Kinetic tests: Sources of uncertainty (cont.)

- Length of tests
  - 20 weeks is standard length; too short for most materials, especially if higher NP
  - Sulfides>carbonates>silicates
  - If NOT high in sulfur content, low in buffering capacity and/or potentially highly reactive, need 2-3 yrs to reach steady state conditions; NP/AP>1 takes > 1 yr
    - Lapakko: tailings with 1.3 wt% calcite and 6.6 wt% pyrite took 112 weeks to generate acid
    - Lapakko: mix of rotary kiln fines and rock with 2.1 wt% S from Duluth complex took 581 weeks to produce acid

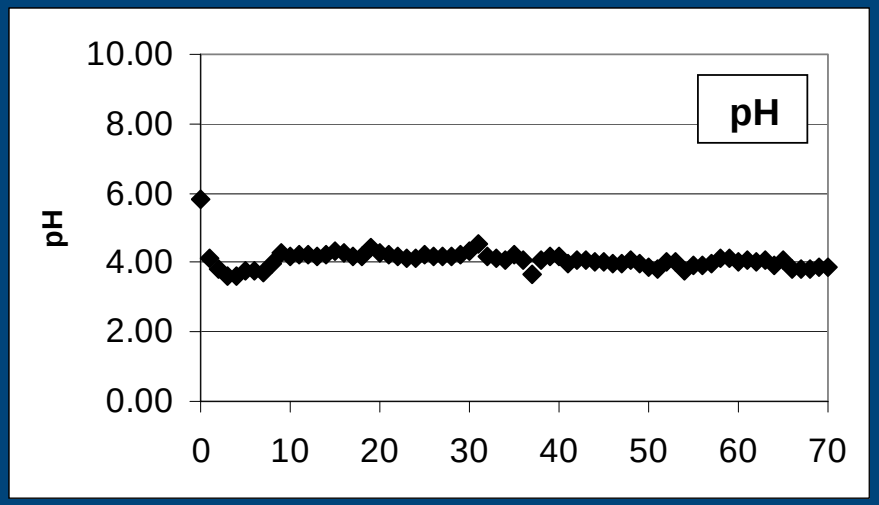
Kinetic tests: Length of tests (cont.)

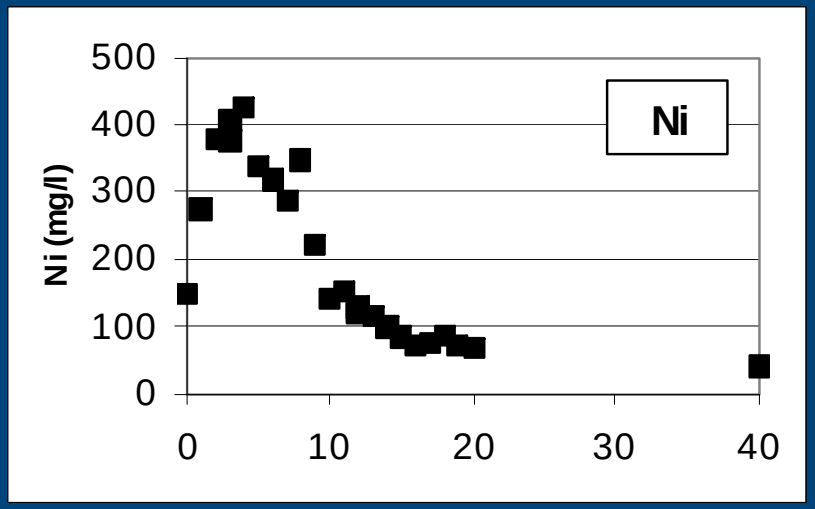




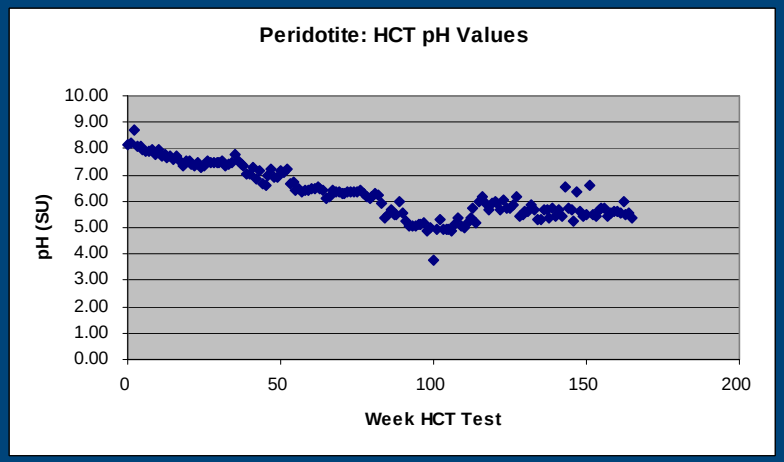
Nicholson and Rinker, 2000: neutral pH conditions

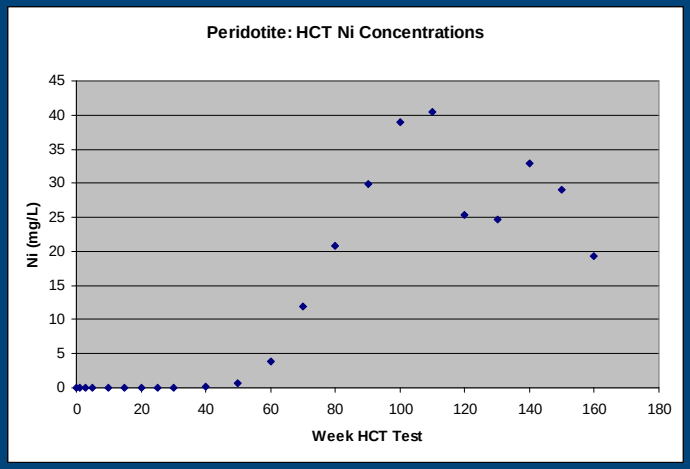
Kinetic tests: Length of tests (cont.)





Eagle Project, MI: Massive sulfide unit, 36.1% S

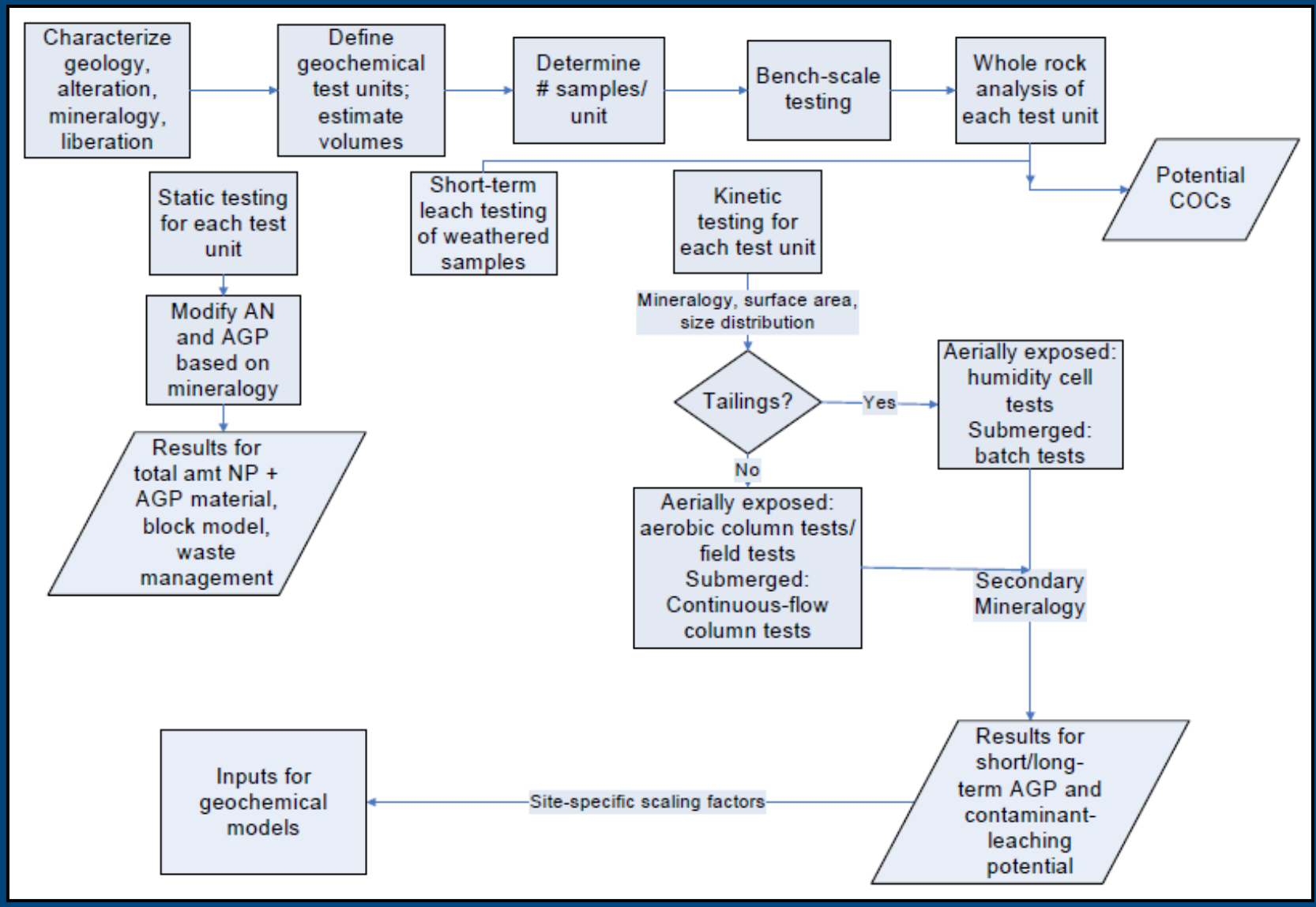




Eagle Project, MI: Peridotite, 2.44% S

Prepared by Maest using results from Geochimica for Eagle Project Hearing, 2008

State-of-the-art Geochemical Characterization



Maest et al., 2005

Guess the pH